HOUSE FLY (MUSCA DOMESTICA L.) SURVIVAL AFTER MECHANICAL INCORPORATION OF POULTRY MANURE INTO FIELD SOIL

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SUMMARY

Land application is often a routine part of manure management. Not only is it a practical means of disposing large amounts of poultry wastes, it is an efficient use of an organic fertilizer. Unfortunately, poultry manure may contain a large number of house fly larvae and pupae that can become a nuisance if they complete development. Mechanical incorporation of poultry manure is often recommended to help reduce odor; it has also been thought to reduce the potential for a fly outbreak. This study examined fly survival following burial in field soil at depths of 0, 1, 3, 6, 9, and 12 in. One quarter of the adult house flies developing from pupae were able to crawl through 12 in. of soil to reach the surface. Survival of flies buried closer to the surface was greater. We compared house fly survival following disk, harrow, and moldboard plow incorporation of manure to surface application. No method of incorporation was better than the surface application. Adult flies reached outbreak proportions 10 days following application and the outbreak lasted another 11 days.

Key words: Fly management, house fly, manure management, nuisance pests, poultry
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DESCRIPTION OF PROBLEM

Manure management is an important consideration in intensive animal agriculture. Whether it is composted, stored in a lagoon, digested, or taken directly from the facility, at some point manure is applied to the land. Valued as organic fertilizer, poultry manure is high in calcium, magnesium, phosphorus, potassium, zinc, and nitrogen [1, 2]. In 1990, broiler, layer, and turkey farms in the U.S. produced an estimated 13,078 million kg of manure, most of which was applied to the land as fertilizer [2]. This practice has sparked

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environmental concerns in three areas: nonpoint source pollution, groundwater contamination, and a source of human pathogens [2, 3]. Of equal importance have been the nuisance insect complaints that arise with the suburbanization of formerly rural areas [4]. Depending on the condition of the manure and the existing insect population, a pest outbreak resulting from land application may be an important liability. Once a nuisance pest outbreak enters the popular press, it effectively creates a negative investment climate for agriculture and the community [5, 6].

Recognizing the relationship between manure management and fly production, producers have used whatever means are available to control pest populations, including chemical, biological, cultural, mechanical, and integrated pest management [7, 8]. Fortunately, pest outbreaks can be avoided with carefully planned manure and pest management. A dry, well-ventilated manure storage area is essential to managing the house fly, *Musca domestica*, particularly in houses designed to store manure beneath the cages. Manure moisture greater than 50% promotes fly growth and development. Frequently walking the pit area in search of fly breeding sites and water leaks gives forewarning of potential problem areas.

Knowledge of house fly life stages allows the producer to predict when problems may arise. The female house fly deposits 75–200 eggs in manure, spilled feed, and other moist, warm, decaying organic material [9]. Female flies may lay up to six batches of eggs in their lifetime. The larvae hatch from the eggs in 12–24 hr. The larvae complete development in 4–7 days, passing through three growth phases or instars as they grow. First and second instar development is usually completed in 48 hr; the third instar requires an additional 2–4 days. Mature larvae form a reddish-brown case from the larval skin, called a puparium, in which they pupate. After undergoing metamorphosis, the adult fly emerges from the pupa after 3–4 days. The rate of development depends upon temperature, with the least time required during the warm summer months.

House flies are an important pest of the poultry industry and are frequently the cause of nuisance complaints. Poultry manure may contain a large number of fly larvae and pupae. Spreading a thin layer of poultry manure on agricultural fields encourages drying and reduces fly development [10]. Removing manure during cold winter months can reduce nuisance complaints, because temperatures of 8°C (46°F) or colder retard fly development or kill fly larvae and pupae [9, 10, 11]. Operational demands that force the removal of manure during the warmer months when insects remain active leave producers with few options. Mechanical incorporation of the manure into the field soil is often recommended to help reduce odors. Although mechanical incorporation is thought to have an impact on fly survival, there is no research base to support this supposition. The present study was designed to measure the survival of house flies buried in field soil and the impact of mechanical incorporation of poultry manure on fly survival. Our objectives were to determine the survival of house fly larvae and pupae buried in field soil at various depths, and to evaluate house fly survival following incorporation of manure into field soil using different farm equipment.

Materials and Methods

BURIED HOUSE FLY STUDY

Buried house fly survival was evaluated under summer field conditions. Experiments were conducted on deep, well-drained, medium-textured Howard Gravel Loam soil of a fallow field at the Thompson Research Farm, Freeville, NY. Laboratory-reared house flies were sorted by age into three replicated groups of 50, and placed in capped 25-cc medication vials containing 5 cc of dry wheat bran. Second and third instar larvae, as well as pupae, were buried in loose field soil at depths of 0, 3, 8, 15, 23, and 33 cm (approximately 0, 1, 3, 6, 9, and 12 in.). No manure was added to the soil.

House fly survival was indicated by the number of adult house flies successfully emerging from the soil beneath inverted cone cylinder traps [12]. Adult fly emergence traps were placed directly over the burial site. Traps were pressed 5 cm into the soil and a bank of soil was packed against the side of the trap to prevent the flies from escaping. All emerging adult flies were removed and counted from each trap each day of inspection. Emergence traps were checked on Days 7, 10, 14, 17, 21, 24, and 28. All flies were removed from the trap upon inspection.

A subsequent experiment was designed to determine the effects of manure on the survival of second instar larvae. Second instar larvae were sorted into 12 treatment groups of 50 larvae each. Treatment groups were buried in field soil as previously described, with the exception that half (6 groups) were buried without manure and remaining (6 groups) treatment groups were buried with the addition of 25 cc of fresh poultry manure. This experiment was replicated twice. Larvae and larvae plus manure were buried and their survival determined as described above.

MANURE INCORPORATION STUDY

A small poultry house containing 2500 layers was selected for this study. No insecticides had been used to control the rapidly growing fly population. The poultry house had recently been repopulated, and the manure depth was approximately 25 cm (10 in.). In subsequent experiments the manure depth was greater. The manure was sub-sampled with a tulip bulb planter (125 cc) at 15 randomly selected sites. Individual samples were placed in Burlese-tulgren funnels to extract the larvae. Larvae were collected and preserved in 70% ethanol.

The remaining manure was removed from the poultry house and loaded into a side-delivery manure spreader. Approximately 6.3 m^3 (224 ft^3) of manure was spread on 1220 m^2 (4000 ft^2 or 0.092 acres) of field at an average depth of 0.0052 m^3/m^2 (0.056 ft^3/ft^2). Spread manure was again sampled to determine fly mortality incurred by the flailing action of the manure spreader. Samples were handled as described above.

Treatments were assigned to 3.05 × 15.25 meter rows (10 × 50 ft) and replicated twice (Figure 1). Treatments included: control (no incorporation), harrow (15 cm depth), disk (7 cm), and moldboard plow (33 cm). Manure in harrow and disk treatments was incorporated with four passes of the implement and plow treatment with one pass. Seven inverted cone cylinder traps [12] were randomly placed on each row, covering 1% of the treated surface area. Traps were pressed into the soil and banked to prevent fly escapes. Emergence traps were inspected on Days 7, 10, 14, 17, 21, 24, and 28. Upon inspection all flies were removed from each trap and counted. Soil temperatures were recorded during the experimental period.

The impact of mechanical incorporation on fly survival was evaluated in three replicated experiments during the months of July, August, and September. Analysis of variance was used to compare house fly survival between treatments. Standard error of the means was calculated from individual treatments. Data were analyzed using general linear model [13].

Results and Discussion

BURIED HOUSE FLY STUDY

House fly pupae buried under 3 and 8 cm of soil successfully eclosed and emerged as adult flies. Pupae buried 15, 23, and 33 cm were less likely to survive burial (Figure 2); however, 24% of the fly pupae buried 33 cm reached the surface as adult flies. Adult house fly emergence by buried third instar larvae was greater than that of buried pupae, although emergence was delayed about 1 wk. Under natural conditions, third instar larvae are quite active, especially during the wandering phase before pupation. It is very likely that, unlike pupae, third instar larvae migrated through the soil and pupated near the soil surface, allowing the newly eclosed adult flies less travel distance to reach the soil surface. No second instar larvae survived burial in the first experiment.

In the subsequent experiment, second instar larval survival remained very low if manure was not present in the soil (Figure 3). However, the addition of manure to the burial site provided sufficient nutrition for the larvae to develop normally and emerge from the soil as adult flies. Interestingly, house fly larvae require very little manure to complete development. Sand containing only 0.47% manure solids (bovine) and 4.74% moisture was sufficient to support normal fly development [14].

MANURE INCORPORATION STUDY

Core samples of the poultry manure collected from the poultry house averaged 154 flies per 125 cc manure sample. Third instar larvae made up 77% of the flies sampled. House fly populations in the caged layer house were relatively high when the manure was removed in July (246/sample) and September

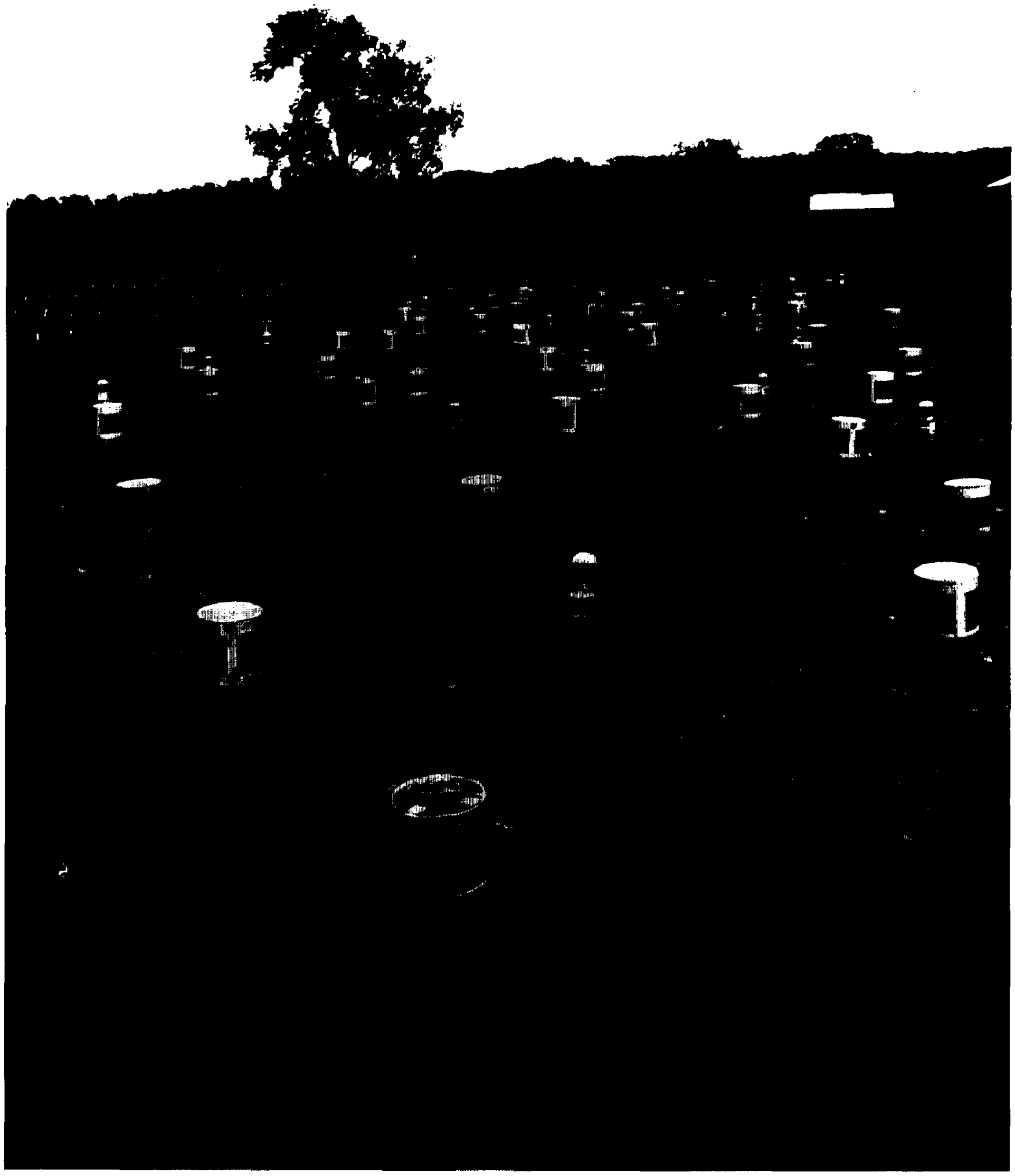

FIGURE 1. Field site layout and location of emergence traps for manure incorporation study

(192/sample). Overall test means were reduced because fly populations were significantly lower in the August test (24/sample).

Manure was thrown 10–12 m, with greater deposits falling within 3–4 m of the manure spreader. Fly larvae were visibly stunned from the flailing action of the manure spreader. Within 30 min of manure application, however, many stunned larvae recovered and began to move about. Regardless of this apparent recovery, results of the post-spreading manure sampling indicated that only 11% of the flies survived.

Incorporation tests demonstrated that moldboard plow reduced mean house fly survival (38.0±5.3) more than disk (45.0±6.6), harrow (48.0±5.3), and the control (51.0±6.4), but these differences were not significant ($P < .382$). The lack of significance was, in part, a result of variation between

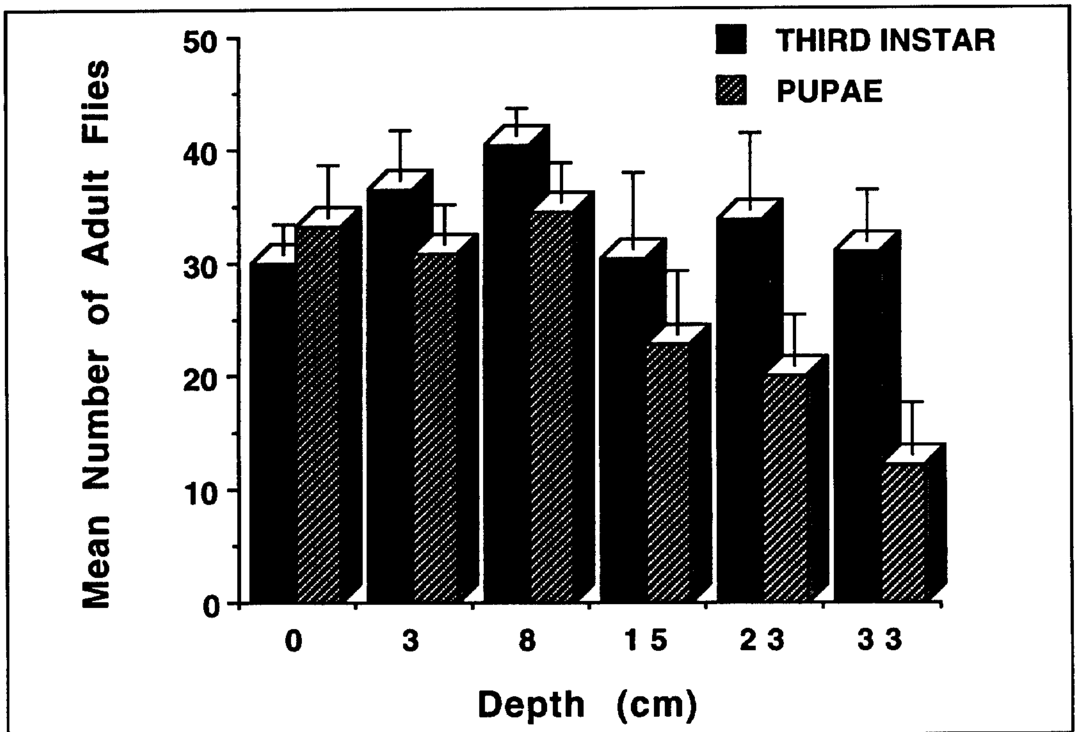

FIGURE 2. Survival of house fly pupae and third instar larvae buried in loose soil at 0, 3, 8, 15, 23, and 33 cm depths

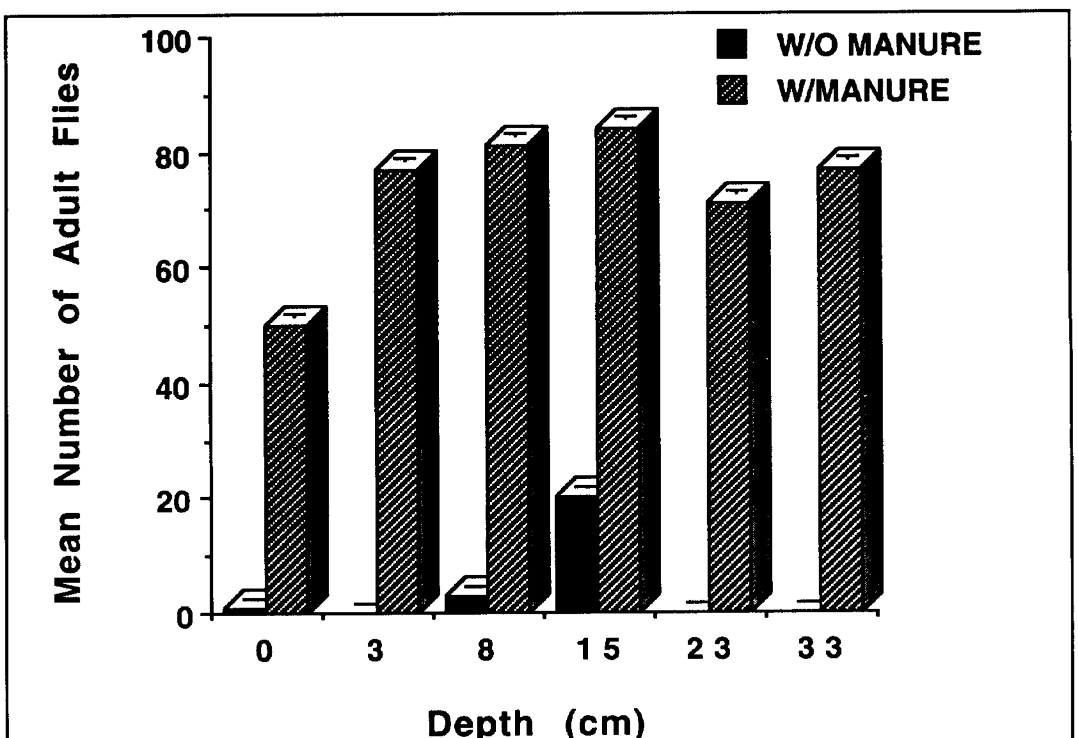

FIGURE 3. Survival of second instar house fly larvae buried with and without manure in loose soil at 0, 3, 8, 15, 23, and 33 cm depths

samples. Adult flies emerged from field soil for 21 days (Figure 4). Fly emergence from field soil began within 3 days of application. Few flies were collected from the traps on Days 3 and 7. Surviving house fly pupae were the likely source of this early emergence. Most house fly emergence occurred 10–17 days following incorporation regardless of treatment. Fly emergence nearly ceased by 21 days.

Average surface soil temperature during the July test was 28.7°C (Table 1). Soil temperature at 33 cm depth was more than 4° cooler, 24.3°C. August temperatures were warmer and September soil temperatures were coolest. Differences in soil temperature were expected to influence the developmental time of larvae in the soil. House fly larvae complete development in 5–6 days at 30°C and complete pupation in 4–5 days [9]. Because cooler soil temperatures slow the developmental time, we expected adult house flies to emerge from the soil sooner in August than in either July or September. Interestingly, most flies emerged from the soil on Day 10 regardless of test month. We suspect the uneven age structure of the immature fly population obscured the temperature effects. It is likely that a more dramatic temperature effect would have been observed in more controlled environments.

Extrapolating from the July core samples, nearly 11 million house flies were removed from the poultry house in one manure spreader. As the manure was spread on the field, the flailing action of the manure spreader caused 89% mortality. We estimate that about 1.2 million flies survived the manure spreader. Moldboard plowing had the most deleterious impact on fly survival. With 25% of the flies surviving burial to 33 cm (12 in.), we could expect about 302,000 adult flies to emerge from the field. Given an equivalent larval density, a commercial caged layer house of 100,000 birds would produce about 440 million flies, most of which would be killed by spreading the manure. Still, without incorporation, we could expect 48.4 million flies to emerge from the field. Consequently, field application of manure continues to pose a threat of pest outbreaks. If frequent manure removal is the management practice of choice, it should be spread daily. Removing manure only during the cold winter months continues to be the best alternative to daily manure cleanout.

Year-round fly management programs that maintain fly populations at tolerable levels reduce the chance of nuisance complaints. Integrated pest management (IPM) strategies emphasize keeping the manure dry (<50%

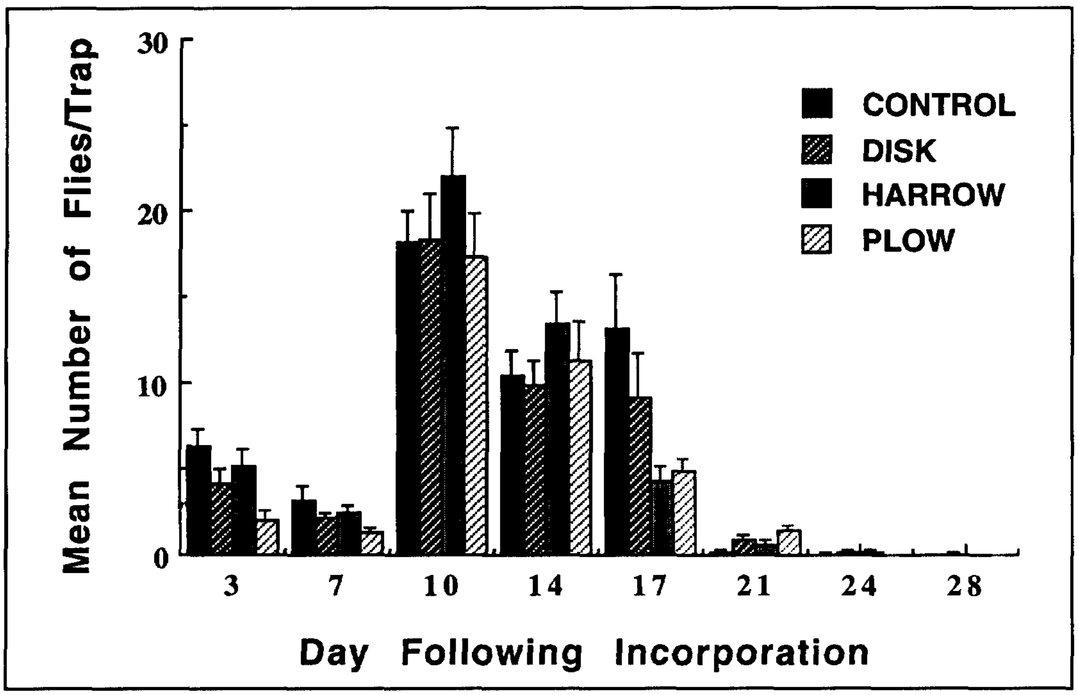

FIGURE 4. Adult house fly emergence from field soil following mechanical incorporation of manure

TABLE 1. Air and soil temperatures at five different depths in a fallow field at Freeville, NY

SOIL DEPTH (cm)	MONTH		
	July	August	September
0	28.7	32.3	26.9
3	28.0	31.8	26.2
8	26.6	29.9	23.9
15	25.6	28.3	22.0
33	24.3	26.9	21.3
Ambient Air	26.9	30.8	28.0

moisture), biological control through augmentative releases of parasitoids and predators, and the judicious use of insecticides, to slow the insecticide resistance and minimize the impact on biological control agents [10]. Future studies will focus on pre-spreading handling of manure to reduce or eliminate insect populations. In-house composting may increase temperatures sufficiently to kill pest populations, or perhaps innovative designs for manure handling equipment may be beneficial.

Conclusions and Applications

1. House flies buried 33 cm (12 in.) in field soil completed development and successfully emerged as adult flies.
2. The flailing action of the manure spreader caused significant fly mortality.
3. Mechanical incorporation had minimal impact on fly survival, and no method was significantly better than surface application.
4. When temperatures favor fly development an outbreak can be expected 10 days following the land application of fly-laden manure.

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